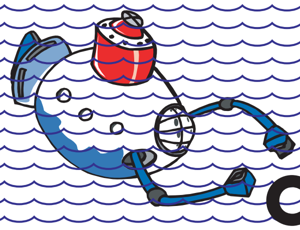

Chemosynthesis for the Classroom

Focus

Chemosynthetic bacteria

Grade Level

9-12 (Chemistry/Biology)

Focus Question

What changes affect succession in the development of chemosynthetic bacterial communities?

Learning Objectives

Students will observe the development of chemosynthetic bacterial communities.

Students will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive.

Students will be able to explain the process of chemosynthesis.

Students will be able to explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Additional Information for Teachers of Deaf Students

In addition to the words listed as key words, the following words should be part of the vocabulary list.

Oxidizing
Hydrogen sulfide
Hydrocarbon gases
Seep
Sediment
Continental margins
Methane
Polychaete worm
Phylum
Chemosynthetic bacteria
Hemoglobin
Gills
Vinogradsky column

The key words are integral to the unit but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. It will also be very helpful to copy the vocabulary list and hand it out to the students to read after the lesson to reinforce what was covered as the six week project continues.

Materials

- ❒ Directions for setting up Winogradsky columns from http://topex-www.jpl.nasa.gov/education/activities
- ❒ Black mud from a local river, lake, or estuary, approximately 500 ml for each student group
- ❒ Water from the same source used to obtain black mud, approximately 3 liters for each student group
- ❒ 500 ml graduated cylinder, two for each student group
- ❒ Calcium sulfate (Plaster of Paris), 80 g for each student group
- ❒ 500 ml jar or beaker
- ❒ Stirring rod
- ❒ Straw or small pieces of filter paper, 50 g for

each student group
- ❒ Sodium bicarbonate (baking soda), 4 g for each student group
- ❒ Crushed multivitamin pill, one for each student group
- ❒ Plastic wrap
- ❒ Rubber bands
- ❒ Source of artificial light
- ❒ Tape and markers for labelling graduated cylinders
- ❒ Flashlight with red cellophane over lens
- ❒ Optional: microscopes and materials for making wet mounts

Audio/Visual Materials

None

Teaching Time

One 45-minute class period to set up columns, approximately 15 minutes at weekly intervals for six weeks to make observations, and one 45-minute class period for presentation and discussion of results

Seating Arrangement

Groups of four students

Maximum Number of Students

20

Key Words

Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Vestimentifera
Trophosome
Succession

Background Information

One of the major scientific discoveries of the last 100 years is the presence of extensive deep sea communities that do not depend upon sunlight as their primary source of energy. Instead, these communities derive their energy from chemicals through a process called chemosynthesis (in contrast to photosynthesis in which sunlight is the basic energy source). Some chemosynthetic communities have been found near underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food chain. These bacteria obtain energy by oxidizing hydrogen sulfide to sulfur:

$CO_2 + 4H_2S + O_2 > CH_2O + 4S + 3H_2O$

(carbon dioxide plus sulfur dioxide plus oxygen yields organic matter, sulfur, and water). Visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities.

Other deep-sea chemosynthetic communities are found in areas where hydrocarbon gases (often methane and hydrogen sulfide) and oil seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth. Typical features of communities that have been studied so far include mounds of frozen crystals of methane and water called methane hydrate ice, that are home to polychete worms. Brine pools, containing water four times saltier than normal seawater, have also been found. Researchers often find dead fish floating in the brine pool, apparently killed by the high salinity.

Where hydrogen sulfide is present, large tube-worms known as vestimentiferans (formerly classified within the phylum Pogonophora; recently Pogonophora and Vestimentifera have been included in the phylum Annelida) are often found, sometimes growing in clusters of millions of individuals. These unusual animals do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome, that contains chemosynthetic bacteria. Vestimentiferans have tentacles that extend into the water. The tentacles are bright red due to the presence of hemoglobin which can absorb hydrogen sulfide and oxygen which are transported to the bacteria in the trophosome. The bacteria produce organic molecules that provide nutrition to the tube worm. A similar symbiotic relationship is found in clams and mussels that have chemosynthetic bacteria living in their gills. Bacteria are also found living independently from other organisms in large bacterial mats. A variety of other organisms are also found in cold seep communities, and probably use tubeworms, mussels, and bacterial mats as sources of food. These include snails, eels, sea stars, crabs, lobsters, isopods, sea cucumbers, and fishes. Specific relationships between these organisms have not been well-studied.
The Gulf of Mexico contains the largest reservoir of fossil fuel in the continental U.S., and the geology of the area has been intensively studied for more than 50 years. While cold seep communities were discovered in the Gulf more than 20 years ago, the biology of these communities has been studied at only three sites less than 20 km apart. Exploring for new cold seep sites and studying the biology and ecology of the organisms that live there is the focus of the Ocean Exploration 2002 Gulf of Mexico Expedition.

This activity focuses on chemosynthetic bacteria similar to those that are the base of food webs in cold seep communities. Black mud from a local water body is incubated in a glass cylinder (called a Winogradsky column) with a source of chemical energy (calcium sulfate) and organic material (straw or filter paper) to grow a succession of chemosynthetic bacteria over a period of six weeks. This activity was originally developed by the Orange County Marine Institute/San Juan Institute Activity Series, and is available on NASA's Jet Propulsion Laboratory Ocean Planet website at http://topex-www.jpl.nasa.gov/education/activities.

Learning Procedure

1. Lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis. In both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Point out that there are a variety of chemical reactions that can provide this kind of energy. Contrast hydrothermal vent communities with cold-seep communities. Visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community.

2. Have each student group follow procedures given at http://topex-www.jpl.nasa.gov/education/activities for setting up two Winogradsky columns

using locally-collected black mud. Cover each column tightly with plastic wrap and secure with rubber bands. One column should be placed in a darkened area and the other column near a light source (but not in direct sunlight). Students should observe their columns weekly, and record their observations. You may have them make wet mounts for microscopic examination at the end of three and six weeks. Use appropriate safety precautions when making wet mounts, including gloves, antibacterial solution for disposing of slides, and hand washing following completion of the activity.

3. Have each group present and discuss their results. Students should have observed a series of changes in the appearance of the mud in the columns caused by a succession of bacterial species. They should infer that changes caused by one species (for example, the production of waste products) create opportunities for other species. Similarly, changes in the chemical composition of the mud, such as formation of hydrogen sulfide, alter the environment in ways that may favor the growth of other bacterial species. The processes observed in the Winogradsky columns roughly models the development of deep-sea chemosynthetic communities. Ask the students to speculate about what other organisms might appear in the community if these processes were taking place in the area from which the mud was collected.

The BRIDGE Connection

www.vims.edu/BRIDGE/vents.html

The "Me" Connection

Have students write a short essay on why cold seeps might be directly important to their own lives. You may want to offer a hint that perhaps the energy source used by chemosynthetic bacteria could be useful to other species as well (some estimates suggest that there may be more energy locked up in methane hydrate ices than in all other fossil fuels combined!).

Connections to Other Subjects

English/Language Arts, Biology, Earth Science

Evaluation

Have students submit records of their observations and their written interpretation of these observations.

Extensions

Have students investigate more about ancient bacteria and recent findings about physical conditions on some of Jupiter's moons, and report on the implications of chemosynthetic bacteria for the origins of life on Earth and extraterrestrial life
(http://www.ocean.udel.edu/deepsea/level-2/chemistry/bacteria.html
and
http://pubs.usgs.gov/publications/text/dynamic.html#anchor19309449 are useful for this).

Resources

http://oceanexplorer.noaa.gov – Follow the Gulf of Mexico Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.bio.psu.edu/People/Faculty/Fisher/fhome.htm – Web site for the principal investigator on the

Gulf of Mexico expedition
http://www.rps.psu.edu/deep/ – Notes from another expedition exploring deep-sea communities

http://ridge.oce.orst.edu/links/edlinks.html – Links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – Links to other ocean-related web sites

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – early report on cold seep communities.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Chemical reactions
- Interactions of energy and matter

Content Standard C: Life Science

- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Origin and evolution of the Earth system

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Notes/Thoughts/Inspirations